Farrington, I. A.
Thesis 1959

An Evaluation of Two Approaches Used in the Teaching of The Basic Number Facts in Grade Two.

B O S T O N U N I V E R S I T Y

SCHOOL OF EDUCATION

Thesis

AN EVALUATION OF TWO APPROACHES USED IN THE TEACHING OF THE BASIC NUMBER FACTS IN GRADE TWO

Submitted by

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(B.S. in Ed., Boston University, 1947)

In partial fulfillment of the requirements for

the degree of Master of Education

1949

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Aug 26 1919
31305

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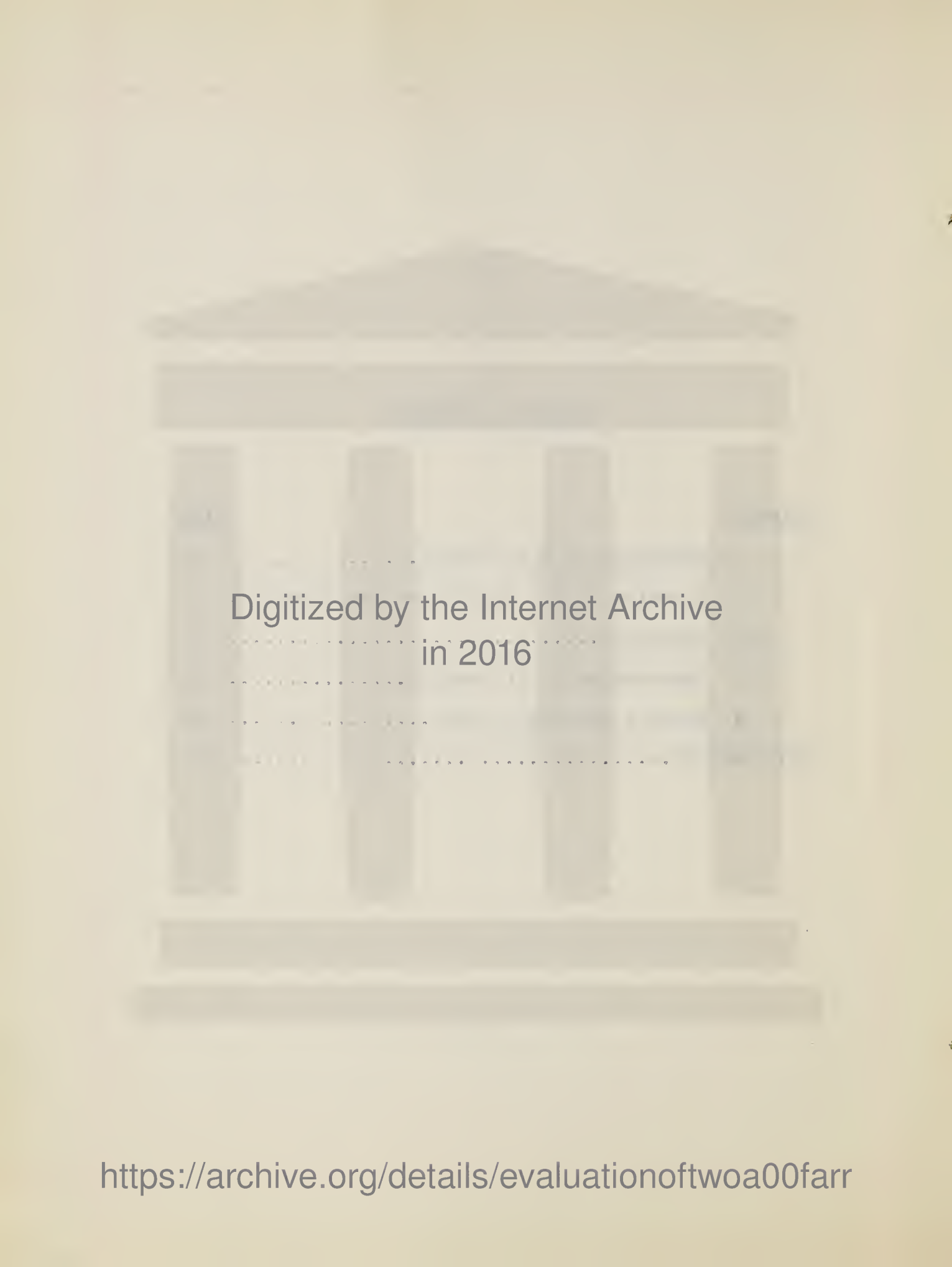

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CHAPTER I

CHAPTER I

The Problem

Many of the research studies done on basic combinations during the past few years have been concerned primarily with the drill approach to the teaching of the basic addition and subtraction combinations. The value of the drill approach has usually been determined through using measures of rate and accuracy. The problem in the present study is to gather some information concerning the place of the drill approach and also the place of the functional approach in the teaching of the basic addition and subtraction combinations in grade two.

The evaluation will include the obtaining of information concerning the mental processes pupils use, as well as information on rate and accuracy. By providing for this additional aspect in the evaluation program, it is felt that greater insight may be obtained concerning the role played by drill, and that played by functional procedures in the teaching of the basic combinations.

CHAPTER II

CHAPTER II

A Review of the Literature and Research

Introduction

The purpose of this investigation was to obtain some information about the place of drill and the place of functional arithmetic in the teaching of the basic addition and subtraction facts in grade two.

Drill is usually referred to as that kind of repetitive process which fixes an association. It may be drill in spelling, arithmetic, language, vocabulary, or any other subject. The main idea is that it is repetitive and usually unvaried.

The functional program has other names, such as Activity Program and Social Application. It is a program of teaching built around one specific topic.

Repetitive drill in arithmetic has long been of concern to educators. Harding, in discussing the arithmetic programs of the past century, points out, "The effectiveness of the teaching-learning process was increasingly judged by the speed and accuracy of performing computational processes. As a result, drill became

the almost universal mode of instruction."[1]

As late as 1925 Newcomb states that, "Efficiency in all subsequent arithmetic is based largely on proficiency in the fundamental processes. It is desirable that pupils attain a reasonable standard of speed and accuracy in these processes."[2]

From this writer and others we see the tendency to judge arithmetic success in accordance with the two criteria of speed and accuracy as obtained through drill. Still other writers have asked the further question concerning whether pupils understand what they are doing. For instance, Mossman asks, "But how much more is accomplished by the meaningful type of arithmetic instead of mechanically flipping symbols."[3]

A survey of the research studies that are concerned with the drill approach and the meaningful approach will help point up the problem more clearly.

Early Research Concerning Drill

Research studies from 1900 to 1925 were definitely

1/ Lowry D. Harding and Inez P. Bryant, "An Experimental Comparison of Drill and Direct Experience in Arithmetic Learning in the Fourth Grade", Journal of Educational Research, XXXVII, January, 1944, p. 321.

2/ R. S. Newcomb, "Effective Drill Exercises in Arithmetic", Journal of Educational Psychology, XVI, February, 1925, pp. 127-131.

3/ Edith L. Mossman, "What Shall It Be - Mechanical Drill or the Development in Understanding All the Whys?", Mathematics Teacher, XXXVIII, March, 1945, p. 103.

concerned with drill, the relative value of various amounts of time for arithmetic losses, and the desirable standards which should be attained.

Brown [4] in 1911 conducted a study using a five-minute drill period each day on the number facts preceding the regular daily arithmetic program in grades six, seven, and eight. He found these five-minute drill periods to be beneficial in developing greater speed and accuracy in the fundamentals of arithmetic.

Following the same idea as Brown, Phillips [5] in 1913 conducted a similar study on the value of daily drill in arithmetic. He used a ten-minute daily drill period with grades six, seven, and eight. He found substantial gains in all phases which he checked -- oral recall, written recall, and reasoning.

Hoover [6] motivated his drill work for third grade through the use of games. He found that the groups who had the benefit of the motivated drill work showed greater gains in improvement than those who had just

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4/ Joseph C. Brown, "An Investigation on the Value of Drill Work in the Fundamental Operations of Arithmetic", Journal of Educational Psychology, II, February, 1911, p. 81.

5/ Frank M. Phillips, "The Value of Daily Drill in Arithmetic", Journal of Educational Psychology, IV, March, 1913, pp. 159-163.

6/ J. H. Hoover, "Motivated Drill Work in Third Grade Arithmetic and Silent Reading", Journal of Educational Research, IV, October, 1929, pp. 200-211.

the repetitive drill.

In summarizing the studies by Brown, Phillips, and Hoover, we find that all of these authors used the drill technique, and all found that drill exercises proved of value in increasing the rate and accuracy with which children could use the basic combinations.

Buswell, in his summary of investigations relating to arithmetic, summarized the studies to 1925, thus: "Experimental studies are quite unanimous concerning the beneficial effects of systematic drill. The amount of improvement varies, depending upon conditions." 7/

Errors in the Fundamental Processes

A slightly different phase of the process of drill was studied by Osborne 8/ and Myers 9/ . Osborne studied school children in grades three to eight. He found that two-thirds of these children made errors and that typical types of wrong errors occurred in practically all grades. Many of the errors pointed clearly to incorrect mental

7/ Guy T. Buswell, "A Summary of Arithmetic Investigations to 1925", Elementary School Journal, XXVI, May-June, 1926, pp. 692-703.

8/ W. J. Osborne, "Errors in the Fundamentals of Arithmetic", Journal of Educational Research, V, April, 1922, pp. 348-349.

9/ G. C. Myers, "The Persistance of Errors in Arithmetic", Journal of Educational Research, X, June, 1924, pp. 17-26.

activity. This is the first mention in the literature that perhaps the mental activity of the children needs to be considered in the teaching of arithmetic.

In studying the errors of children Myers concluded that, "Errors are habits and to the child a wrong answer is as definite as a right one." 10/

Remedial Drill in Arithmetic

Although the value of specific drill periods has been proven, it is important to also note studies which used drill procedures in remedial programs.

Bowdren 11/ and Pucko 12/ each did five case studies of children failing in arithmetic. The children studied were in grades five and six. With short drill periods on their individual problems all of the children studied were able to reach the goal of one hundred percent mastery of the fundamentals.

Gray 13/ set up a program of remedial drill in addition and multiplication in grades six, seven, and

10/ Ibid, p. 26.

11/ W. Bowdren, "Five Case Studies of Arithmetic Failures", Unpublished Master's Thesis, Boston University, 1935, p. 84.

12/ R. Pucko, "Five Case Studies in Arithmetic", Unpublished Master's Thesis, Boston University, 1935, p. 94.

13/ Arthur N. Gray, "An Experiment in Drill in the Addition and Multiplication Processes in Grades Five, Six, Seven, and Eight", Unpublished Master's Thesis, Boston University, 1942, 144 pp.

eight. The two most important conclusions which he set forth were:

1. At the beginning of the experiment there was not a high degree of accuracy in the addition and multiplication processes in any one grade.

2. Accuracy nearing one hundred percent can be acquired by pupils in these grades.

In 1940 Ringer made another study in diagnostic and corrective work in the four fundamentals. Her investigation extended over a period of two years. She was concerned about the need of corrective arithmetic, and concluded, "If the original teaching has been correct and the review has been adequate, no remedial work is necessary. One should strive for preventative teaching, not corrective teaching. Yet, most surveys and studies of test results show that the teaching has not been correct and that corrective procedures are necessary." 14/

Research in the Mental Processes Which Children Use

In 1924, Osborne, in his study of errors, suggested that, "Many of the errors pointed clearly to incorrect

14/ Alberta R. Ringer, "A Two-Year Diagnostic and Corrective Study in the Four Fundamentals of Arithmetic With a Group of Children in Grades Seven and Eight". Unpublished Master's Thesis, Boston University, 1940, p. 7.

mental activity." 15/

The first important study on the mental processes children use, in connection with number facts, was done by Brownell and Chazal in 1935. 16/ At the beginning of a school year Miss Chazal gave a test of the 100 basic addition combinations to sixty-three children in grade three. On the basis of their showing on the test she selected thirty-two children for her study, the nine poorest, thirteen average, and ten highest.

The thirty-two children were then asked to "think out loud" when combinations were presented to them. The responses were checked under the headings of:

Guessing Indirect Solution

Counting Automatic Response

Following this interview twenty school days were spent on repetitive drill on the combinations. It was not motivated drill, and flash cards were used for most of it.

Following this period of special drill, Test A was repeated again as Test B, and Interview 1 was repeated as Interview 2. During the twenty school days following

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15/ W. J. Osborne, op. cit., pp. 348-349.

16/ William Brownell and Charlotte Chazal, "The effect of Premature Drill on Third Grade Arithmetic", Journal of Educational Research, XXIX, September, 1935, pp. 17-28.

Test B and Interview 2, no special drill was given on the combinations. At the end of this period of twenty school days, Test C was given and Interview 3 conducted.

At the end of the testing and interview period Miss Chazal, in analyzing her data according to the criteria of rate and accuracy, found the following results:

	Median Time	Median Errors
Test A	17 minutes	11 errors
Test B	11 minutes	4 errors
Test C	7 minutes	4 errors

From these results Miss Chazal concluded that, "Drill on the combinations in grade three produced results which correspond closely with those reported in the experiments which have been canvassed. It increased efficiency as measured in the usual manner."

The following table gives Miss Chazal's results for the interviews: 17/

Method	Frequency by Interview			Frequency by Interview		
	Int. 1	Int. 2	Int. 3	Int. 1	Int. 2	Int. 3
Counting	116	89	99	22.7%	17.4%	19.3%
Indirect Solution	72	80	65	14.1%	15.6%	12.7%
Guessing	122	93	79	23.8%	18.2%	15.4%
Immediate Recall	202	250	269	39.5%	48.5%	52.5%
Total	512	512	512	100.1%	99.7%	99.9%

17/ W. Brownell and C. Chazal, op. cit., p. 23.

In analyzing her data from the interviews Miss Chazal found that the gains, in mental procedures, as a result of the drill program, were not encouraging. Her conclusion regarding rate and accuracy has been previously presented. She states, "Drill makes little, if any, contribution to growth in quantitative thinking by supplying maturer ways of dealing with numbers." 18/

Miss Chazal's study provided a challenge to other authors, and in 1943 we find another study by Brownell and Carper 19/, which is also concerned with the thought processes.

Referring to research studies up to this time (1943), Brownell and Carper state:

> The evidence with regard to drill procedure is not clear, almost wholly because data is lacking to show what drill does to advance learning. Drill methods do seem to produce a degree of proficiency, though little is known about the permanence and usefulness of what is learned by these methods. There is evidence, admittedly not in connection with the multiplication facts, that children learn otherwise than by repetition, when they do not understand what they are supposed to learn. 20/

18/ W. Brownell and C. Chazal, op. cit., p. 15

19/ William A. Brownell and Doris V. Carper, Learning the Multiplication Combinations, Duke University Press, Durham, No. Carolina, 1948, pp. 17-85.

20/ W. Brownell and D. Carper, op. cit., p. 17

Continuing on, Brownell and Carper again refer to the lack of information on research studies:

> One of the main conclusions to be drawn from the whole body of research is that, as yet, we know exceedingly little about the teaching of the multiplication combinations. Perhaps, the chief reason for our lack of knowledge is that research tells us next to nothing about the way children learn the combinations. 21/

With these statements a whole new idea presents itself. Although the author is referring to the multiplication combinations, addition, subtraction, or division might have been substituted in its place.

Until the present time one hundred percent accuracy with a reasonable rate of speed has been the goal. If the child got 100% on an arithmetic paper he "knew" the combinations. From their study Brownell and Carper concluded:

> Children do not, as has been frequently suggested, "know" or "not know" the combinations. Rather, they know them in different ways and to differing degrees, and these ways and degrees are identifiable in the processes which they use in thinking. 22/

21/ W. Brownell and D. Carper, op. cit., p. 45.

22/ W. Brownell and D. Carper, op. cit., p. 83

Implication of the Research

We may conclude, from previous research, that perhaps the child who gets 100% does not actually "know" the combinations. This is an important idea for teachers, especially those who tend to judge children by the mark which they get on a test paper.

The present study extends the work done by Brownell and Chazal [23], by including both addition and subtraction and by working at a lower grade level. The present study is also an attempt to see the effect of a meaningful program in bringing children to a higher level of mental activity.

The studies by Brownell and his associates opened the door to a new area for those interested in the field of arithmetic research. The instructional value of drill has been proven, but its effect on learning and the thought processes, which children use when solving any basic arithmetic examples, still challenge the interested educator. The possibilities for studies in this field of arithmetic would seem to be unlimited.

23/ W. Brownell and C. Chazal, op. cit., pp. 18-35

CHAPTER III

CHAPTER III

Procedure

Introduction

This study was concerned with obtaining information about the place of drill and the place of meaningful arithmetic in the teaching of the addition and subtraction combinations.

To obtain the necessary information the decision was made to use the testing and interview techniques. Accuracy and speed were checked through a testing program, and information on the mental processes children used was gathered through the use of the interview technique.

Description of the Population

The children used in this study were from a residential community near Boston, Massachusetts. The majority of the children were from average or better than average homes. There are five elementary schools in the town, and a junior and senior high school. The townspeople are keenly interested in their schools and in the constant betterment of them.

Twenty-two of the pupils used in this study were

from a second-grade classroom. The ten other pupils involved in this investigestigation were the second grade pupils from a double grade room, which had both grades one and two. Two children from the second grade room were not used in the study due to their lack of any previous formal work in arithmetic. The second grade room had two teachers during the three-months study, while the double grade had the same teacher during the entire study. All of the children used in the study had been taught the addition combinations with sums to ten, and the subtraction combinations with minuends to ten, in grade one.

Initial Review

During the first two weeks of school a general review of first grade arithmetic was given. This included the basic addition combinations with sums to ten, and the subtraction combinations with minuends to ten, along with counting and a general understanding of number vocabulary.

The basic combinations of addition and subtraction were reviewed orally in order to recall them to the minds of the children. No attempt was made to have the children learn them, and they were told the ones they did not know.

At the end of this period of review and recall the

initial test was given.

Initial Testing

Early in October thirty-two children in grade two were given a written test on forty addition and forty subtraction combinations, with sums and minuends to ten. Zero facts were included in these tests. All of the combinations had been previously taught in grade one and reviewed in grade two.

The addition and subtraction tests were given on separate days. All of the children were assembled in the second grade room. The papers were passed out, blank side up, and then the children were told it was to be an arithmetic game. The word "test" was not used. It was explained that they were to see how many number stories they could do. When they were finished they were to put on the back of their papers the number written on the front board. The tests were timed to the nearest half-minute, and it was stressed to the children that they must copy exactly what was on the board. They were instructed to raise their hands when they had finished and put their heads on the desks after the papers were collected.

For timing, a watch with a second hand was used, and the numbers 1-2-3-4-5, etc., written on the board, each number representing one half-minute. The second

grade teacher marked the time on the board, while the first grade teacher collected the finished papers.

Selection of Study Material

After the results of the first tests were checked, the seven hardest and three easiest examples, according to number of correct responses on each test, were used for Interview I. This gave a total of twenty combinations, ten addition and ten subtraction. The same twenty combinations were used for all of the interviews.

Interview I

Interview I was conducted after the results of Test 1 had been tabulated.

During the first interview it was necessary to establish rapport between pupils and teacher. All of the interviews were with individual pupils. For lunch pupils they were held during a free half-hour period before lunch, and for other pupils they were held at the beginning of each school session. The majority of the pupils stayed for lunch, so this did not interfere with the regular school program.

After rapport had been established the pupil was asked to "think out loud" when the twenty combinations were presented to him, one at a time. His first answer was recorded, and any additional ones supplied by the pupil were also recorded.

The answers were recorded under five headings:

1. Guessing (may also be incorrect automatic response)

The pupil was said to guess if he gave an incorrect response without any apparent thought, or appeared uncertain when giving an answer.

7 -5 "9-no-4."

3 /4 "Is it 9?"

2. Counting

An answer was listed as counting if the pupil used his fingers to find the answer, or counted out loud.

6 /4 "1-2-3-4-5-6-(pause-7-8-9-10--------10."

7 /2 "9" - counted on finders

3. Partial Counting

Partial counting differed from regular counting in that the pupil counted only part of the answer.

6 /3 "7-8-9-------9."

5 /2 "6-7---------7."

4. Indirect Solution

When the pupil used some indirect method to find the answer it was referred to as indirect solution.

3 "3 ⌿ 3 = 6 --- 3 ⌿ 4 = 7--
⌿5 ---now 8."

3 "Ah, 3 ⌿ 5 -- 3 ⌿ 3 = 6 --
⌿5 --7/"

5. Automatic Response

A response was considered automatic if it was given correctly without hesitation.

3 "3 ⌿ 3 = 6."
⌿3

6 "6 - 4 = 2."
-4

The teacher found it easy to establish rapport. The children accepted the procedure as a new game and were eager to play, although no scores were given and no comment was made on their progress.

Drill Teaching Program

During the twenty school days following Interview I five minutes was taken from the regular arithmetic program each day to drill on the combinations used in Interview I. It was just repetitive drill through the use of flash cards and pupil-teacher response. There was no special motivation to learn. The children gave answers to the combinations they knew and they were told

the ones they did no know.

Test 2 and Interview II

At the end of the first teaching period Test 2 was given and Interview II was conducted. The procedures used in Test 1 and Interview I were followed exactly in Test 2 and Interview II. The children were given the same directions and were even more eager to "play the game again. The same method of timing was used.

Functional Teaching Program

At the beginning of the study the primary idea was to evaluate growth in mental processes and rate and accuracy through repetitive drill. As the study progressed it was decided to see what contribution a functional program would make towards growth in rate, accuracy and mental processes.

Therefore, after Test 2 and Interview II were completed, a functional program was instituted with the same group of children under the same classroom conditions. The content from the two previous tests and interviews was used as a basis for the functional program. The results will be referred to as Test 3 and Interview III.

Description of the Functional Program

Since the Christmas season was at hand the theme

of the program was Christmas. From the beginning of the program interest was keen among the children. The work consisted of oral problems and oral combinations suggested by the classroom teacher and by the pupils, such as:

1. Father has 8 Christmas lights on a set. Two do not light. How many are good?
2. Jane put 4 balls on the tree. Sally put on 2. How many balls did Jane and Sally put on the tree?

The children discussed each situation as it was presented to them and figured out how they would solve it, and why. The answer was then given from the group. The combinations incorporated in the work were the same as those used in the drill program.

The program was conducted for twenty school days. At the end of the period Test 3 was given and Interview III was administered.

Test 3 and Interview III

Test 3 and Interview III followed the program of functional teaching. The testing and interview procedures were not changed in any way. The children, by this time, were thoroughly familiar with the procedures. They seemed to enjoy the programs even more than before.

Following Test 3 and Interview III the results of the three tests and three interviews were summarized.

CHAPTER IV

CHAPTER IV

Interpretation of Results

Introduction

The pupils used in this study were thirty-two second grade pupils. Their I.Q.'s ranged from 89 to 114, with a mean I.Q. of 104.

The tests used in this experiment were informal, teacher-built tests, using the basic addition and subtraction combinations. The same test was repeated three times. The results will be referred to as Test 1, Test 2 and Test 3.

Three interviews, each one individually conducted with each pupil, were used to obtain information on mental processes.

Changes in Rate and Accuracy

The first group of tables present information concerning the changes in rate and in the number of errors

made by the pupils in the study.

Table 1 reports the number of pupils who improved, retrogressed, or had no change in the rate of response during each period, Test 1 to Test 2, Test 2 to Test 3, and Test 1 to Test 3.

TABLE 1

NUMBER OF PUPILS WHO RESPONDED TO THE COMBINATIONS AT A FASTER RATE, AT A SLOWER RATE, AND AT THE SAME RATE DURING EACH PERIOD

Tests	Number With Time Decrease		Number With Time Increase		No Change	
	Add.	Subt.	Add.	Subt.	Add.	Subt.
Test 1 to Test 2	26	24	5	6	1	1
Test 2 to Test 3	24	25	3	2	6	2
Test 1 to Test 3	30	27	1	2	1	1

Table 1 shows pupil changes in rate from Test 1 to Test 2, from Test 2 to Test 3, and from Test 1 to Test 3. By the end of the testing period all but five of the pupils showed some decrease in the time which they needed to respond to all of the combinations.

Tables 2 and 3 show by half-minute steps the decrease in time necessary to the addition and subtraction combinations during each period. Thus Table 1 above gives the total number reducing rate while Tables 2 and 3 show the amount of reduction.

TABLE 2

NUMBER OF PUPILS ACHIEVING VARIOUS REDUCTIONS IN THE TIME TAKEN TO RESPOND TO THE BASIC ADDITION COMBINATIONS

	Amount of Decrease in Minutes															
	.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5
Test 1 to Test 2	1	3	3	2	7	2	4	1		1	1		2				
Test 2 to Test 3	9	4	3	1	3	1	1	1						1			
Test 1 to Test 3		3	2	6	3	4	3	4	1				2		2		

CHAPTER V

CHAPTER V

Summary and Conclusions

Summary of the Procedure

Early in October a test of basic combinations previously taught in grade one was given to thirty-two second grade pupils. The order of difficulty was established for the group tested. The seven hardest and three easiest combinations were used for the first interview. During the first interview the children were asked to "think out loud" when the twenty combinations were presented orally to them.

Following Interview I five minutes a day was taken from the regular arithmetic program to drill on the combinations. Repetitive drill with flash cards was used. At the end of this period Test 2 was given and Interview II was conducted. The same combinations used in Test 1 and Interview I were used throughout the study. At the end of Interview II it was decided to continue the experiment for twenty more school days, using a functional program. The functional program was set up and carried out during the next school month with the same group of pupils. At the end of the time Test 3 and Interview III

Table 2 shows only the number of pupils having reductions in the amount of time they needed to respond to the basic addition combinations. With the exception of a few scattered scores the decreases in time ranged from .5 minutes to 4 minutes for each testing period. The period from Test 1 to Test 2 (Drill Program) had four pupils with decreases in time of more than four minutes, while the period from Test 2 to Test 3 (Functional Program) had only one.

Only one pupil had no change in time from Test 1 to Test 2, while five worked at a slower rate than they had previously. The slower rate ranged from .5 minutes to 1 minute, with the exception of one pupil who took 4.5 minutes more to complete the work.

From Test 2 to Test 3 one pupil again had no change in time, while three showed time increases of .5 minutes each.

TABLE 3

NUMBER OF PUPILS ACHIEVING VARIOUS REDUCTIONS IN THE TIME TAKEN TO RESPOND TO THE BASIC SUBTRACTION COMBINATIONS

	Amount of Decrease in Minutes																		
	.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0
Test 1 to Test 2	1	1	5	3	4	1	2					2	1	3						1
Test 2 to Test 3	4	3	3	2	3	1	5			1	2		1							
Test 1 to Test 3	1	1	2	3	3	2	2	3	1	1		2	1	2			1	1		1

Table 3 shows only the number of pupils having reductions in the amount of time they needed to respond to the basic subtraction combinations. Most of the decreases in time for the subtraction combinations ranged between .5 minutes and 3.5 minutes. The period from Test 1 to Test 2 (Drill Program) had seven pupils with decreases in time of more than 3.5 minutes, the greatest decrease in time being 10 minutes. The period from Test 2 to Test 3 (Functional Program) had only four with decreases of more than 3.5 minutes, the greatest decrease being 6.5 minutes.

From Test 1 to Test 2 only one pupil had no change in time, while from Test 2 to Test 3 two had no change in the time it took them to complete the work on the subtraction combinations.

From Test 1 to Test 2 six pupils worked at a slower rate than they had previously. The time ranged from .5 minutes to 3.5 minutes. From Test 2 to Test 3 only two pupils worked slower than they had previously, one at 1.0 minutes and one at 2.0 minutes slower.

In the tables which follow, the center of interest changes from improvement in the rate of response to the combinations to accuracy as represented by a diminishing number of errors.

Table 4 reports the number of pupils who made fewer errors, and those who made more errors, and those who had

no change in accuracy of response to the combinations during such period.

TABLE 4

NUMBER OF PUPILS WHO HAD FEWER ERRORS, WHO HAD MORE ERRORS, AND WHO HAD NO CHANGE IN THE NUMBER OF ERRORS DURING EACH PERIOD

Tests	Number With Fewer Errors		Number With More Errors		No Change	
	Add.	Subt.	Add.	Subt.	Add.	Subt.
Test 1 to Test 2	15	17	2	1	15	12
Test 2 to Test 3	8	9	3	10	23	10
Test 1 to Test 3	17	20	6	3	9	6

This table shows pupil changes in rate from Test 1 to Test 2, from Test 2 to Test 3, and from Test 1 to Test 3. Subtraction from Test 2 to Test 3 shows less improvement than any other area, with ten pupils making more errors than they had previously made.

Tables 5 and 6 show the distribution of the changes in the number of errors made by pupils during each per-

iod. Table 4 presented the total number making fewer errors, while Tables 5 and 6 show by how many errors each of these scores was reduced.

TABLE 5

NUMBER OF PUPILS SHOWING VARIOUS REDUCTIONS IN THE NUMBER OF ERRORS MADE IN RESPONDING TO THE ADDITION COMBINATIONS

	Amount of Decrease in Errors																				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Test 1 to Test 2	4	2	2	1						1	1				1				1		1	1
Test 2 to Test 3	5	3																				
Test 1 to Test 3	8	2	1	1	1							1			1		1		1			

Table 5 shows only the number of pupils having reductions in the number of errors they made when responding to the basic addition combinations. From Test 1 to Test 2 a total of fifteen pupils reduced the number of errors they had made previously. The amount of decrease in errors was widely scattered, with more than half of the fifteen pupils having decreases of four or fewer errors.

Fifteen pupils made the same number of errors during this period and two increased the number of errors by one error each.

From Test 2 to Test 3 only eight pupils reduced the number of errors they had made previously. Five made one less error and three made two less errors.

During the same period twenty-three pupils had no change in accuracy, while three made more errors. The number of increased errors ranged from one to four errors.

TABLE 6

NUMBER OF PUPILS SHOWING VARIOUS REDUCTIONS IN THE NUMBER OF ERRORS MADE IN RESPONDING TO THE SUBTRACTION COMBINATIONS

	Amount of Decrease in Errors																				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Test 1 to Test 2	4	1	1	2		1	1			1			2		1		1					2
Test 2 to Test 3	6		1	1						1												
Test 1 to Test 3	4	3		1	3	1	2		1			1	1		1			1		1		

Table 6 shows only the number of pupils having reductions in the number of errors they made when responding to the basic subtraction combinations. From Test 1 to Test 2 seventeen pupils reduced the number of errors they had made previously. The amount of decrease in errors varies greatly, with ten of the pupils decreasing their errors by seven or less. The other seven scores ranged from ten to twenty-two.

From Test 2 to Test 3 only nine pupils reduced the number of errors they had made previously. Eight made four or less errors, while one made ten less errors. From Test 1 to Test 2 only one pupil had an increase in errors. It was an increase of five errors.

During the next period, Test 2 to Test 3, there was a sharp rise in the number who had an increase in errors they had made previously. Ten pupils increased the number of errors they had made. Eight of these pupils made from one to three more errors, while two made eleven more errors. It will be remembered that this was the period during which the functional program was conducted.

From Test 1 to Test 2 twelve pupils made the same number of errors they had made previously, and from Test 2 to Test 3 ten did not change the number of errors they had made.

Changes in Mental Processes Used by the Children

Summary of Changes for the Group

In the tables which follow, the data will include the mental responses for all the pupils interviewed, as well as detailed responses for some of the pupils.

Table 7 shows the total number of responses for each of the mental processes. The information is separated by interviews. There were ten addition and ten subtraction facts for which responses were recorded. Since thirty children were used in the interviews, a total of three hundred addition and three hundred subtraction responses were recorded during each interview.

TABLE 7

NUMBER OF RESPONSES FOR EACH MENTAL PROCESS DURING INTERVIEWS I, II, AND III

Methods Used by Pupils	Interview I		Interview II		Interview III	
	Add.	Subt.	Add.	Subt.	Add.	Subt.
Counting	19	37	19	15	9	7
Partial Counting	36	22	21	17	10	4
Guessing	35	39	30	46	20	30
Indirect Solution	11	1	-	-	-	-
Automatic Response	199	201	230	222	261	249

A study of Table 7 shows that Automatic Response was the type of mental process used most frequently by the pupils, and Indirect Solution was the one least used. At the beginning of the study the pupils had a high degree of proficiency in the use of Automatic Response. The trend toward the use of more mature mental processes is evident throughout the interviews. The only place where the trend is not evident is guessing responses in Interview II. As has been previously noted, this was

the interview which took place just before the change from the drill program to the functional program.

Tables 8 and 9 provide for comparisons in terms of percents of the number of times each mental approach was utilized.

TABLE 8

PERCENT OF TIMES EACH MENTAL PROCESS WAS USED IN RESPONDING TO THE ADDITION COMBINATIONS

Interview	Guessing	Counting	Partial Counting	Indirect Solution	Automatic Response
I	11%	6%	12%	4%	67%
II	10%	6%	6%	0	74%
III	6%	3%	3%	0	88%

TABLE 9

PERCENT OF TIMES EACH MENTAL PROCESS WAS USED IN RESPONDING TO THE SUBTRACTION COMBINATIONS

Interview	Guessing	Counting	Partial Counting	Indirect Solution	Automatic Response
I	13%	12%	8%	0	67%
II	14%	5%	4%	0	77%
III	11%	5%	1%	0	83%

Tables 8 and 9 show the number of times each mental process was used by the pupils when responding to the addition and subtraction combinations. The change toward more mature mental processes is only slightly greater in the addition than in the subtraction combination. In addition Interview III had 5% fewer pupils guessing than in Interview I, 3% fewer pupils using counting, 9% fewer pupils partial counting, and indirect solution was completely abolished. Twenty-one percent more pupils were using automatic response as a method of solving these combinations.

In subtraction Interview III had 2% fewer pupils using guessing, 7% fewer pupils using counting, 7% fewer pupils using partial counting, and no pupils using indi-

rect solution. It had sixteen percent fewer who were using automatic response.

At the end of Interview I the percentage of pupils using automatic response as a mental process was the same in addition and subtraction, 67%. At the end of Interview III, automatic responses in addition were 88% of the total responses, while the responses in subtraction were 83%.

Interview II gives the percentage of times each mental process was used after the drill program, while Interview III gives the results after the functional program. The trend toward more mature mental processes was much the same in addition and subtraction. The only area which showed no change was counting in subtraction, Interview II to Interview III.

Individual Responses of Selected Pupils

Tables 10, 11, 12, 13, 14, and 15 are individual records of responses of certain selected pupils to the combinations presented to them during the interviews. Tables 10, 12, and 14 are the responses to the addition combinations, and Tables 11, 13, and 15 are the responses to the subtraction combinations.

Tables 10 and 11 show the individual responses of pupil six to the addition and subtraction facts presented during the three interviews. Pupil six showed very small

gains in the use of more mature mental processes from Interview I to Interview II. At the beginning of the study he could be classed as a guesser. During Interview II his answers still show that guessing is the process being used to find the answers. Interview III shows a decided change to counting. In almost every instance pupil six used his fingers to count out the answers.

TABLE 10

RESPONSES OF PUPIL 6 TO THE ADDITION FACTS

	Interview I	Interview II	Interview III
6 ∠4	"Let me see now, 7-8-9-10 ----10."	"Is it 8?"	Counted to 10.
3 ∠5	"2-no-take away-now-oh-8 ------8."	"3 ∠ 5 = 8."	"7" - counted on fingers.
8 ∠2	"9-no-10."	"8 ∠ 2 = 10."	Same Response (10)
3 ∠4	"Is it 9?"	"Is it 6?"	"3 ∠ 4 = 9."
7 ∠2	"7 ∠ 2 = 9."	"Same Response (9)	"9" - counted on fingers.
6 ∠3	"6 ∠ 3 = 9."	"6 ∠ 3 = 5."	"9" - counted on fingers.
5 ∠3	"6-7-8---8."	"3 ∠ 5 = 8."	"8" - counted on fingers.
2 ∠2	"2 ∠ 2 = 4."	Same Response (4)	Same Response (4)
8 ∠1	"8 ∠ 1 = 9."	Same Response (9)	Same Response (9)
5 ∠0	"5 ∠ 0 = 5."	Same Response (5)	Same Response (5)

TABLE 11

RESPONSES OF PUPIL 6 TO THE SUBTRACTION FACTS

	Interview I	Interview II	Interview III
7 -5	"9-no-4."	"7 - 5 = 2."	Same Response (2)
8 -2	"1-2-(pause)-3-4-5-6-7-8-8"	"8 - 2 = 5."	"4" - counted on fingers.
9 -6	"9 - 6 = 3."	Same Response (3)	"3" - counted on fingers.
8 -4	"8 - 4 = 5."	"8 - 4 = 4."	"4" - counted on fingers.
9 -5	"9 - 5 = 3."	"9 - 5 = 7."	"4" - counted on fingers.
9 -2	"Is it 7?"	"9 - 2 = 8."	"7" - counted on fingers.
10 -3	"10 - 3 = 7."	Same Response (7)	"10 - 3 = 6." counted on fingers.
5 -4	"5 - 4 = 1."	Same Response (1)	Same Response (1)
3 -1	"3 - 1 = 2."	Same Response (2)	Same Response (2)
2 -1	"2 - 1 = 1."	Same Response (1)	Same Response (1)

Tables 12 and 13 give the responses of pupil fifteen to the addition and subtraction facts presented during the interviews. During Interview I it would be difficult to class pupil fifteen's responses in addition under one heading, counting. Indirect solution, guessing, and automatic response are all represented. During Interview II it became guessing and automatic response. By the end of Interview III pupil fifteen had resorted almost wholly to counting. All of this analysis has been concerned with the responses to the addition facts. The responses to the subtraction facts present a little different picture. With the exception of the two easiest facts presented, pupil fifteen used counting as his method of solving the subtraction facts. His method could be termed a type of block counting. During Interview II his method changed and he was using automatic response and some guessing. By Interview III automatic response, counting and guessing were being used to solve the subtraction facts.

TABLE 12

RESPONSES OF PUPIL 15 TO THE ADDITION FACTS

	Interview I	Interview II	Interview III
6 ∠4	"1-2-3-4-5-6- (pause) 7-8-9- 10 --------10."	"6 ∠ 4 = 10."	Same Response (10)
3 ∠5	"Ah, 3 ∠ 5 -- 3 ∠ 3 = 6 --7."	"3 ∠ 5 = 7."	"1-2-3-4-5- (pause) 6-7- 8 -------8."
8 ∠2	"8 ∠ 2 = 10."	"8 ∠ 2 = 9."	"8 ∠ 2 = 10."
3 ∠4	"3 ∠ 4 = 7." counted to 7	"3 ∠ 4 = 6."	"5-6-7-3."
7 ∠2	"7 ∠ 2 = 9."	Same Response (9)	"1-2-3-4-5-6- (pause) 7-8-9- ----------9."
6 ∠3	"6 ∠ 3 = 7."	"6 ∠ 3 = 9."	"1-2-3-4-5-6- (pause) 7-8-9- ----------9."
5 ∠3	"5 ∠ 3 = 8." counted to 8	"5 ∠ 3 = 8."	Same Response (8)
2 ∠2	"2 ∠ 2 = 4."	Same Response (4)	Same Response (4)
8 ∠1	"8 ∠ 1 = 9."	Same Response (9)	Same Response (9)
5 ∠0	"5 ∠ 0 = 5."	Same Response (5)	Same Response (5)

TABLE 13

RESPONSES OF PUPIL 15 TO THE SUBTRACTION FACTS

	Interview I	Interview II	Interview III
7 -5	"1-2-3-4-5-(pause)-6-7-9-2."	"7 - 5 = 2."	Same Response (2)
8 -2	"1-2-(pause)-3-4-5-6-7-8-6."	"8 - 6 = 2."	"1-2-(pause)-3-4-5-6-7-8-6."
9 -6	"1-2-3-4-5-6-(pause)-7-8-9-9."	"9 - 6 = 5."	"Ah - 10."
8 -4	"1-2-3-4-(pause) 5-6-7-8-4."	"8 - 4 = 4."	Same Response (4)
9 -5	"1-2-3-4-5-(pause) -6-7-8-9-4."	"9 - 5 = 11."	"9 - 5 = 4."
9 -2	"1-2-(pause)-3-4-5-6-7-8-9-9."	"9 - 2 = 6."	"9 - 2 = 5."
10 -3	"1-2-3-(pause) - 4-5-6-7-8-9-10 -10."	"10 - 3 = 7."	Same Response (7)
5 -4	"1-2-3-4-(pause)-5-1."	"5 - 4 = 1."	Same Response (1)
3 -1	"3 - 1 = 2."	Same Response (2)	Same Response (2)
2 -1	"2 - 1 = 1."	"2 - 1 = 3."	"2 - 1 = 1."

Tables 14 and 15 give the responses of pupil eighteen to the addition and subtraction combinations presented during the three interviews. Pupil eighteen failed to change to any great extent the mental processes he was using to solve the basic combinations. At the beginning of the study partial counting was his method of attack on the combinations, and throughout the study, both in addition and subtraction, he continued to use this process.

TABLE 14

RESPONSES OF PUPIL 18 TO THE ADDITION FACTS

	Interview I	Interview II	Interview III
6 +4	"7-8-9-10-------10."	"7-8-9-10-------10."	"6 + 4 = 10."
3 +5	"6-7-8---10."	"3 + 5 = 8."	"6-7-8----8."
8 +2	"8 + 2 = 10."	Same Response (10)	Same Response (10)
3 +4	"4-5-6-7--7."	"4-5-6-7--7."	"3 + 4 = 7."
7 +2	"8-9------9."	"8-9------2."	"8-9-----9."
6 +3	"7-8-9----9."	"7-8-9----3."	"7-8-9---9."
5 +3	"6-7-8----8."	"7-no-8---8."	"6-7-8---8."
2 +2	"2 + 2 = 4."	Same Response (4)	Same Response (4)
8 +1	"8 + 1 = 9."	Same Response (9)	Same Response (9)
5 +0	"5 + 0 = 5."	Same Response (5)	Same Response (5)

TABLE 15

RESPONSES OF PUPIL 18 TO THE SUBTRACTION FACTS

	Interview I	Interview II	Interview III
7 -5	"6-7----7."	"6-7----2."	"7 - 5 = 5."
8 -2	"3-4-5-6-7-8-------8."	"8 - 2 = 6."	"1-2-(pause)-3-4-5-6-7-8-------6."
9 -6	"7-8-9---3."	"7-8-9----3."	"9 - 6 = 3."
8 -4	"5-6-7-8-4."	"8 - 4 = 4."	Same Response (4)
9 -5	"6-7-8-9-4."	"6-7-8-9-4."	"5-(pause)-6-7-8-9---4."
9 -2	"3-4-5-6-7-8-9------9."	"8-no-6."	"1-2-(pause)-3-4-5-6-7-8-9---------7."
10 -3	"4-5-6-7-8-9-10-----7."	"10 - 3 = 7."	"Is it 8?"
5 -4	"5 - 4 = 1."	Same Response (1)	Same Response (1)
3 -1	"2-3----2."	"3 - 1 = 2."	Same Response (2)
2 -1	"2 - 1 = 1."	Same Response (1)	Same Response (1)

were conducted.

The results of the three tests and interviews were tabulated.

Basic Conclusions From This Study

1. Repetitive drill led to improvement in rate and accuracy.
2. The functional program led to improvement in rate and accuracy to about the same extent as the drill program.
3. Several of the children used in the study, when taught by drill procedures, continued to use the mental processes which they had used previously. Drill helped very little to change the mental processes which these pupils were using. Likewise, the functional program failed to provide any great change in the pupils' method of solution.
4. Neither drill nor the functional program guaranteed that children would use a higher mental process than the one which they had previously found would serve their needs.

Implications for Teaching

1. One hundred percent accuracy does not guarantee that children are using mature mental processes.

2. A program of drill will increase speed and accuracy, but does little to change mental processes.
3. A functional program may increase speed and accuracy. It will not necessarily be effective in developing the use of more mature mental processes.
4. The program in arithmetic must make provisions for discovering and improving the level of maturity of the pupil's mental processes. The optimum program will first provide that the children are using the most efficient mental steps, and then will attempt to improve the rate and accuracy of the performance at this high level.

Limitations of the Study

1. Only a small sampling of pupils was used in the study.
2. The study was done in only one school and in only one community.
3. The second grade classroom, which had most of the pupils used in the study, was subjected to a change of teachers during the progress of the investigation.
4. The pupils used in the study had a high level of ability in solving the basic combinations

at the beginning of the study.

5. The study is exploratory in nature, designed to obtain some information concerning the functional approach to the teaching of the basic combinations, as well as information about the drill approach. It is not intended to be a comprehensive study.

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